Lung Cancer in Sussex County, Delaware:

Findings from the Indian River Community-Level Survey (IRCLS)

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Abstract

Sussex County citizens have suggested that residential proximity to the Indian River Power Plant (IRPP) may be contributing to elevated lung cancer rates in the Indian River area. Indeed, results from a 2007 study by the Delaware Division of Public Health (DPH) found that the 2000-04 lung cancer incidence rate for the six zip code region defined as Indian River was significantly elevated compared to rates for Sussex County, Delaware, and the U.S.

In response to this finding, Delaware contacted the National Cancer Institute (NCI) and the Centers for Disease Control and Prevention (CDC) for further guidance. Both federal agencies advised DPH to first determine if tobacco use was a major contributing factor to the elevated lung cancer rate in the Indian River area. If tobacco use was not found to be a contributing factor, other lung cancer risk factors should then be investigated.

In 2008, DPH initiated the Indian River Community-Level Survey (IRCLS) – a survey-based study designed to collect risk factor data from Sussex County residents diagnosed with lung cancer. Findings from the IRCLS were supplemented with surveillance data from the Delaware Cancer Registry (DCR).

DCR surveillance data revealed that males account for virtually all of the elevation in the Indian River lung cancer rate. The 2000-04 and 2001-05 lung cancer incidence rates for Indian River males were significantly elevated compared to rates for Sussex County, Delaware, and the U.S. However, lung cancer incidence rates for Indian River females were not significantly elevated compared to the county or state rates for either 5-year time period.

Using IRCLS data, odds ratios were calculated for the following lung cancer risk factors: tobacco use (including past, current, heavy, and long-term use), exposure to secondhand smoke, family history of lung cancer, history of nonmalignant lung disease (chronic bronchitis and/or emphysema), occupational exposure (including working in high-risk industries and exposure to known lung carcinogens), ever having lived in a residence that received private well water, and ever having used wood burning as the primary method of heating the home. Given public concern over environmental exposure in Sussex County, DPH calculated odds ratios for long-term Sussex County residency (15 years or more) as a possible lung cancer risk factor.

Within Indian River, three lung cancer risk factors reached a level of statistical significance: (1) ever smokers were 10.5 times more likely to have developed lung cancer compared to never smokers; (2) current smokers were 17.5 times more likely to have developed the disease compared to non-current smokers; and (3) participants who had ever worked in one or more high-risk industries were 3.4 times more likely to have developed lung cancer compared to those who had never worked in a high-risk industry.

Regardless of lung cancer status, Indian River participants were significantly more likely than non-Indian River participants to be heavy smokers and to have worked in a high-risk industry. Thus, baseline prevalence rates suggest that the Indian River community may have a unique lung cancer risk factor profile.

When considered as a whole, findings from the IRCLS do not rule out tobacco use and occupational exposure as contributing factors to the elevated lung cancer rate in the Indian River area. Given the magnitude of odds ratios, tobacco use is the major factor that explains the original findings of elevated lung cancer rates in the Indian River area of Sussex County, Delaware.

Introduction

From 2001-05, the number of lung cancer cases diagnosed among Delawareans reached 3,476. Lung cancer accounted for nearly 16% of all cancers diagnosed in the state during this 5-year time period.[1] Following prostate cancer for males and breast cancer for females, lung cancer is the second most commonly diagnosed cancer among males and females in Delaware.

While lung cancer ranks second in the state for new cancer cases, it ranks first in the state for cancer deaths. Lung cancer accounted for 31% of all cancer deaths in Delaware from 2001-05. During this time period, 2,673 Delawareans died from the disease.[1]

Historically, Delaware's lung cancer incidence and mortality rates have exceeded those of the U.S. This trend persisted into the 21st century. For 2001-05, Delaware's lung cancer incidence rates were 25% and 27% higher than the U.S. rates for men and women, respectively.[1, 2] During this time period, Delaware ranked 9th in the nation for lung cancer incidence and 11th in the nation for lung cancer mortality.[2, 3]

Encouragingly, Delaware has made substantial progress in reducing its lung cancer burden. From 1991-95 to 2001-05, Delaware's male lung cancer incidence rate decreased 20% while the comparable U.S. rate fell 17%.[1] Since the 1980s, in both Delaware and the U.S., lung cancer incidence rates have increased for females.[1,a] Nevertheless, the rate of increase in lung cancer incidence for females has been slower in Delaware compared to the U.S. From 1991-95 to 2001-05, Delaware's female lung cancer incidence rate increased just 2% while the comparable U.S. rate increased 4%.[1]

Statewide efforts to reduce lung cancer rates have focused on minimizing exposure to known lung cancer risk factors. An estimated 87% of lung cancers are caused by smoking cigarettes, cigars, or pipes.[4] Smoking rates have sharply declined among Delawareans. In 1982, 30% of Delaware adults smoked cigarettes.[5] By the 1990s, Delaware's smoking rate had declined to approximately 25%; currently, 18% of Delawareans smoke cigarettes.[6]

Often overlooked is the significant role that exposure to secondhand tobacco smoke, radon gas, and certain carcinogens (e.g., asbestos, heavy metals) play in the development of lung cancer. The Delaware Division of Public Health (DPH), in conjunction with the Delaware Cancer Consortium and the Department of Natural Resources and Environmental Control, has initiated risk reduction efforts that target these lesser discussed lung cancer risk factors. The Delaware Healthy Homes initiative provides free radon testing kits to qualified Delaware homeowners. Additionally, in 2008, Delaware began the process of retrofitting buses in the Wilmington metropolitan area with state-of-the-art air filters to reduce diesel exhaust.

In 2007, DPH initiated the Indian River Lung Cancer Investigation at the request of citizens living in the area of the Indian River Power Plant who were concerned that exposure to emissions from the plant was responsible for an increased risk of cancer. Indeed, results from the 2007 study found that the 2000-04 lung cancer incidence rate for the Indian River area (defined as a six zip code region in southeastern Sussex County) was significantly elevated compared to the rates for Sussex County, Delaware, and the U.S. (Table 1).[7]

[a] This trend is explained by the fact that, nationwide, the smoking prevalence rate for females peaked later than for males. While male lung cancer incidence rates have already begun to show a noticeable decline, corresponding declines in female lung cancer incidence rates are expected to occur in the future.

Table 1: 2000-04 Age-Adjusted Lung Cancer Incidence Rates, Findings from the 2007 Indian River Lung Cancer Investigation[7]

• United States	63.0 (62.5, 63.4)
o Delaware	76.9 (74.3, 79.5)
• Sussex County	79.1 (66.6, 91.5)
⇨ Indian River Area	**104.7** (94.8, 114.6)

All rates are per 100,000 and age-adjusted to the 2000 U.S. standard population.
Values in parentheses represent lower and upper 95% confidence limits.
Bolded rate is significantly elevated compared to the Sussex County, Delaware, and U.S. rates.
Sources: Surveillance, Epidemiology, and End Results Program, National Cancer Institute, 2007; DCR, 2009.

In response to this finding, Delaware contacted the National Cancer Institute (NCI) and the Centers for Disease Control and Prevention (CDC) for further guidance. Both federal agencies advised DPH to first determine if tobacco use was a major contributing factor to the elevated lung cancer rate in the Indian River area. If tobacco use was not found to be a contributing factor, other lung cancer risk factors should then be investigated.

Following federal guidance, the specific purpose of the Indian River Community-Level Survey (IRCLS) was to determine the extent to which tobacco use contributed to the elevated lung cancer rate in the Indian River area.

The IRCLS was implemented as a survey-based study that collected risk factor data from Sussex County residents, both with and without lung cancer. Data collection began in April 2008 and continued through October 2008. Analyses focused on identifying risk factors most strongly associated with a diagnosis of lung cancer.

The remainder of this report is divided into three sections. The Methods section includes technical information related to Delaware Cancer Registry (DCR) surveillance data and IRCLS sampling and analysis strategies. The Results section presents both DCR surveillance data and findings from the IRCLS. Finally, the Discussion section summarizes current lung cancer trends in the Indian River area, reviews strengths and limitations of the IRCLS, and offers suggestions for future studies.

Methods

A. Defining the Indian River Area

Using the same definition as the 2007 DPH investigation, the IRCLS identified Indian River as the region in southeastern Sussex County comprising the following six zip codes: 19939, 19945, 19947, 19966, 19970, and 19975. For the remainder of this report, the term "Indian River" refers to the region encompassing these six zip codes. The term "non-Indian River" refers to the remainder of Sussex County that lies outside of these six zip codes.

Sussex County is the most rural of Delaware's three counties. According to the U.S. Census Bureau, 53% of Sussex County residents reside in areas considered rural compared to 36% of Kent County residents and just 6% of New Castle County residents.[8] As a result, 4.1% of Sussex County residents diagnosed with lung cancer from 2000-07 (N=67 cases) had P.O. Boxes recorded as their primary mailing addresses. For these cases, it is difficult to verify patients' residential zip code at the time of diagnosis. This is due to the fact that a resident's P.O. Box may be located in one zip code while the resident actually resides in a neighboring zip code. Rather than exclude cases with P.O. Box addresses from analyses, DPH included these cases under the assumption that they had been accurately assigned to the correct zip code at diagnosis using geocoding software.

B. DCR Surveillance Data

In April 2009, DPH obtained from the DCR a file of all lung cancer cases diagnosed in Sussex County from 2000-07 (N=1,629). At this time, DCR data were verified complete and accurate through diagnosis year 2007.

DPH analyzed surveillance data by Indian River status (Indian River vs. non-Indian River), sex, race, stage at diagnosis, and age at diagnosis. DPH also calculated 5-year average annual age-adjusted lung cancer incidence rates for the Indian River area, Sussex County, and Delaware for the 2000-04 and 2001-05 time periods. U.S. rates for the 2000-04 and 2001-05 time periods were obtained from the National Cancer Institute.[b] Five-year rates were calculated for both sexes combined, as well as for males and females, separately.

C. Calculating Age-Adjusted Lung Cancer Incidence Rates

To calculate 2000-04 and 2001-05 lung cancer incidence rates, cross-tabulations were performed to determine the number of lung cancer cases diagnosed among residents in each 5-year age group. These frequencies were used to calculate crude and age-adjusted incidence rates for a specific geographic region (i.e., Indian River, Sussex County, or Delaware). Age-adjusted incidence rates were calculated from crude incidence rates. Whereas crude incidence rates fail to consider the age structure of a population, age-adjusted incidence rates take into account the age distribution of the population at risk. Therefore, age-adjusted incidence rates are useful for comparing rates between two populations that differ in age composition.

[b] While DPH also calculated 2002-06 and 2003-07 lung cancer incidence rates for the Indian River area, comparison data at the county, state, and national levels are not yet available.

To calculate crude incidence rates, the number of cancer cases diagnosed in a particular age group in a particular geographic area was divided by the population size for that specific cohort; these values were then multiplied by 100,000. To determine the 2001-05 crude incidence rate for an entire geographic area, the number of cancer cases diagnosed in the geographic area over the 5-year period was divided by the total population of the area for the same 5-year period, and this value was multiplied by 100,000.

To calculate age-adjusted incidence rates, crude incidence rates for each age group were multiplied by the appropriate 2000 U.S. Standard Million Population weight.[9] Age-adjusted incidence rates for each of the 5-year age groups were summed to yield the age-adjusted incidence rate for an entire geographic area.

Ninety-five percent (95%) confidence intervals were calculated for each age-adjusted incidence rate (see Section D, below).

D. Calculating and Interpreting Confidence Intervals

Cancer incidence rates are estimated values; by nature, all estimated values are associated with some degree of uncertainty. Confidence intervals were calculated to quantify the degree of uncertainty associated with each cancer incidence rate.

Confidence intervals represent the range of values in which the cancer rate could reasonably fall. Consistent with the majority of research studies, the IRCLS used 95% confidence intervals to estimate this range of possible values (i.e., α=0.05). When constructed properly, a 95% confidence interval includes the true cancer rate 95% of the time. The best estimate of the cancer incidence rate in a particular area is the incidence rate, itself. However, the rate could reasonably lie anywhere between the lower confidence limit (LCL) and the upper confidence limit (UCL). Because of this, a confidence interval is sometimes called the "margin of error."

Ninety-five percent (95%) confidence intervals were calculated for the Indian River area, Sussex County, and Delaware using the formulas below:

$$\text{Lower Confidence Limit} = \text{AA Rate} - 1.96\left(\frac{(\text{AA Rate})}{\sqrt{\#\text{ Cases}}}\right)$$

$$\text{Upper Confidence Limit} = \text{AA Rate} + 1.96\left(\frac{(\text{AA Rate})}{\sqrt{\#\text{ Cases}}}\right),$$

where AA Rate = the age-adjusted incidence rate for a particular geographic area.

Ninety-five percent (95%) confidence intervals for U.S. rates were obtained from the National Cancer Institute.

The degree of uncertainty associated with an incidence rate is illustrated by the width of its confidence interval. Very wide confidence intervals mean that the incidence rate is estimated with a large degree of uncertainty. Confidence intervals (shown in parentheses in Tables 1, 4, and 5) represent the range of values in which the cancer rate could reasonably fall. For example, as shown in Table 4, the best estimate of the 2001-05 lung cancer rate in the Indian River area is 107.4 per 100,000; however, the rate could reasonably fall anywhere between 97.3 and 117.4 per 100,000.

Confidence intervals are used to determine if the amount by which two incidence rates differ is statistically significant. If the confidence interval for one incidence rate overlaps with the confidence interval for another incidence rate, the two rates are not significantly different. When two rates are not significantly different, it is commonly interpreted as “no meaningful difference” between the rates.

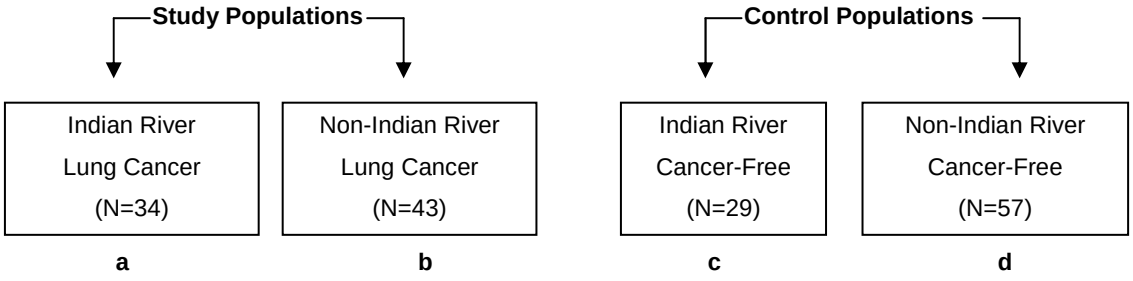
On the other hand, if the confidence interval for one incidence rate does not overlap with the confidence interval for another incidence rate, the two rates are significantly different. When one rate is significantly different from another rate, the difference between the rates is larger than would be expected by chance alone.

DPH compared lung cancer incidence rates for the Indian River area to lung cancer incidence rates for Sussex County, Delaware, and the U.S. This allowed DPH to identify whether Indian River lung cancer rates were significantly greater than rates at the county, state, and national levels. If the confidence interval for the Indian River lung cancer rate overlapped with the confidence interval for the county, state, or national rates, the Indian River rate was not significantly different from the other rates. If the confidence interval for the Indian River rate did not overlap with the confidence interval for the county, state, or national rate, the Indian River rate was significantly different from the other rates. In Tables 1, 4, and 5, if the Indian River lung cancer rate was significantly greater than the rates for Sussex County, Delaware, and the U.S., the rate appears in **bold** font.

E. IRCLS Recruitment Protocol

The IRCLS was a survey-based study designed to collect risk factor data from Sussex County residents diagnosed with lung cancer on or after January 1, 2004. DPH collected data from four populations of Sussex County residents: two study populations ((a) Indian River residents with lung cancer and (b) non-Indian River residents with lung cancer) and two control populations ((c) cancer-free Indian River residents and (d) cancer-free non-Indian River residents) (Figure 1).

Figure 1: IRCLS Study and Control Populations



The Delaware Health and Social Services Human Subjects Review Board approved all components of the IRCLS study design. Data collection began in April 2008 and continued through October 2008. Lung cancer participants and proxy reporters were interviewed by DPH employees. Cancer-free participants were interviewed by contracted surveyors affiliated with Advances in Management, Inc. All interviewers completed five hours of rigorous survey methods training prior to data collection. Additionally, IRCLS staff conducted mock interview

sessions with interviewers; mock interview sessions were designed to reinforce content from the survey methods training courses. Trained interviewers collected self-report data from participants using a standardized survey format. Interviews were conducted over the telephone or in-person, according to participants' preferences. Surveys took approximately 30 minutes to complete.

In March 2008, the DCR provided DPH with a file of all Sussex County residents diagnosed with lung cancer on or after January 1, 2004. At the time of data recruitment, the most recent date of lung cancer diagnosis reported to the DCR was December 20, 2007. DPH contacted all 211 known living Indian River and non-Indian River residents diagnosed with lung cancer on or after January 1, 2004. Of these 211 individuals, 77 agreed to participate in the IRCLS, reflecting a lung cancer participation rate of 37%.[c]

Lung cancer participants were limited to those who provided written informed consent and met the following eligibility criteria: (1) Sussex County resident at the time of diagnosis; (2) diagnosed with primary lung and bronchus cancer (ICD-0-3: 340-349); (3) diagnosed on or after January 1, 2004; and (4) diagnosed with malignant tumors only.

DPH recruited cancer-free Indian River and non-Indian River participants by randomly contacting Sussex County residents with publicly-listed telephone numbers. A total of 255 Sussex County residents were contacted for participation in the IRCLS. If the resident agreed to participate, he or she was asked if they had previously been diagnosed with any form of cancer. Of the 255 residents contacted by DPH, 86 agreed to participate and met all eligibility criteria, reflecting a cancer-free participation rate of 34%.

Cancer-free participants were limited to those who provided written informed consent and met the following eligibility criteria: (1) Sussex County resident at the time of the study; (2) age 50 or older at the time of the study; and (3) never diagnosed with any form of cancer. Cancer-free participants were required to be age 50 or older in an effort to maintain a similar age structure between lung cancer and cancer-free participants.

IRCLS participants were financially compensated for their time. In addition to financial compensation, DPH provided participants with follow-up information about accessing cancer screening, cancer treatment, and emotional support services in Delaware.

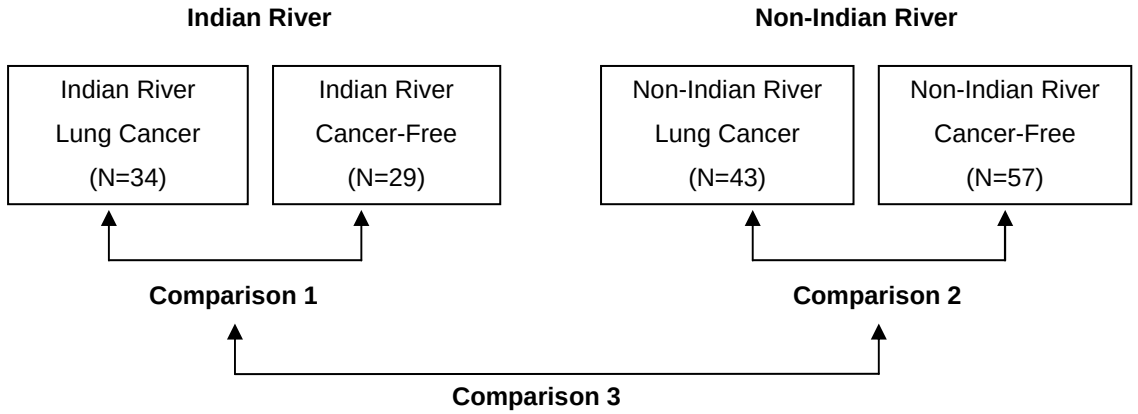
F. IRCLS Data Analysis Strategy

IRCLS analyses were performed using SAS 9.1 software. Analyses focused on three groups of comparisons (Figure 2). First, analyses identified demographic and risk factor prevalence differences between lung cancer and cancer-free participants residing in the Indian River area ("Comparison 1" in Figure 2). Second, analyses identified differences between lung cancer and cancer-free participants residing in the non-Indian River area ("Comparison 2" in Figure 2). Finally, analyses compared the magnitude of differences between lung cancer and cancer-free participants in the Indian River area to the magnitude of differences between lung cancer and cancer-free participants in the non-Indian River area ("Comparison 3" in Figure 2). The first two

[c] Data for 6 of the 77 lung cancer participants were provided by proxy reporters. Proxy reporters were immediate family members of Sussex County lung cancer decedents. Of the six surveys completed by proxy reporters, four were completed on behalf of non-Indian River residents diagnosed with lung cancer. The remaining two proxy report surveys were completed on behalf of Indian River residents diagnosed with lung cancer.

groups of comparisons identified differences at the individual-level (lung cancer vs. cancer-free participants) while the third set of comparisons identified differences at the community-level (Indian River vs. non-Indian River areas).

Figure 2: IRCLS Data Analysis Strategy



G. Calculating and Interpreting Odds Ratios

An odds ratio indicates how strongly an exposure variable is related to an outcome of interest. Mathematically, odds ratios are calculated by assigning participants to one of four unique cells (A, B, C, or D) in a 2x2 grid design of exposure status vs. outcome status (Figure 3).
In terms of the IRCLS, the exposed and non-exposed groups refer to those participants who do and do not have a particular lung cancer risk factor, respectively. The outcome represents a diagnosis of lung cancer.

To calculate the odds ratio of disease, the odds of the disease occurring in the exposed group (A / B) are divided by the odds of the disease occurring in the non-exposed group (C / D). The equation (A / B) / (C / D) is mathematically equivalent to the equation (A x D) / (B x C). The latter equation is used to calculate odds ratios of disease.

Figure 3: Calculating Odds Ratio of Disease

	Lung Cancer	Cancer-Free	
Risk Factor Present	A	B	Odds of disease among those with risk factor = A / B
Risk Factor Absent	C	D	Odds of disease among those without risk factor = C / D

Odds ratio of disease = (A / B) / (C / D) = (A x D) / (B x C)

In studies like the IRCLS, odds ratios help identify disease risk factors that are strongly associated with the development of the disease. As with age-adjusted incidence rates, 95%

confidence intervals are used to determine whether odds ratios are statistically significant. The formulas for calculating 95% confidence intervals for odds ratios are as follows:

Lower Confidence Limit of $\ln(OR) = \ln(OR) - 1.96(1/A + 1/B + 1/C + 1/D)^{0.5}$

Upper Confidence Limit of $\ln(OR) = \ln(OR) + 1.96(1/A + 1/B + 1/C + 1/D)^{0.5}$

If an odds ratio was greater than 1.0, *and* the confidence interval did not contain the value 1.0, participants with the risk factor were significantly more likely to have developed lung cancer than participants without the risk factor. Regardless of the size of the odds ratio, if the confidence interval contained the value 1.0, participants with the risk factor were no more likely to have developed lung cancer than participants without the risk factor.

Odds ratios were calculated for the following lung cancer risk factors: tobacco use (including past, current, heavy, and long-term use), exposure to secondhand tobacco smoke, family history of lung cancer, past history of lung cancer disease precursors (chronic bronchitis and/or emphysema), occupational exposure (including working in high-risk industries and exposure to known lung carcinogens), ever having lived in a residence that received private well water, and ever having used wood burning as the primary method of heating the home. Given public concern over environmental exposure in Sussex County, DPH also calculated odds ratios for long-term Sussex County residency (15 years or more) as a possible lung cancer risk factor.

For each lung cancer risk factor, two odds ratios were calculated: one for Indian River residents and one for non-Indian River residents.

Results

A. Lung Cancer in Sussex County, Delaware: 2000-07

To provide background data on lung cancer trends in Sussex County, DPH accessed surveillance data from the Delaware Cancer Registry (DCR). At the time of data analysis, DCR data were verified complete and accurate through diagnosis year 2007. Therefore, the DCR surveillance data presented below reflects Sussex County lung cancer trends from 2000-07.

From 2000-07, 1,629 cases of lung cancer were diagnosed among Sussex County residents. All 1,629 cases involved malignant lung cancers (i.e., tumors that are capable of destroying nearby tissue and spreading to other parts of the body).

Table 2 provides a breakdown of Sussex County lung cancer cases by Indian River status and year of diagnosis. Table 3 displays a breakdown of Sussex County lung cancer cases by Indian River status, sex, race, and stage at diagnosis.

Table 2: Annual Lung Cancer Diagnoses by Indian River Status, Sussex County, Delaware: 2000-07

	2000 N (%)	**2001** N (%)	**2002** N (%)	**2003** N (%)	**2004** N (%)	**2005** N (%)	**2006** N (%)	**2007** N (%)	**Total (2000-07)** N (%)
Indian River	87 (44.6)	90 (53.9)	78 (44.8)	86 (43.2)	89 (43.8)	98 (37.4)	93 (40.3)	68 (34.3)	689 (42.3)
Non-Indian River	108 (55.4)	77 (46.1)	96 (55.2)	113 (56.8)	114 (56.2)	164 (62.6)	138 (59.7)	130 (65.7)	940 (57.7)
Total	195	167	174	199	203	262	231	198	1,629

"Indian River" refers to the region of southeastern Sussex County made up by zip codes 19939, 19945, 19947, 19966, 19970, and 19975; "non-Indian River" refers to the remainder of Sussex County that falls outside of the six zip code region. Source: DCR, 2009.

Table 3: Demographic Profile of Lung Cancer Cases by Indian River Status, Sussex County, Delaware: 2000-07

	Indian River N (%)	**Non-Indian River** N (%)	**Total** N (%)
Total	689	940	1,629
Male	411 (59.6)	511 (54.4)	922 (56.6)
Female	278 (40.4)	429 (45.6)	707 (43.4)
Caucasian	623 (90.4)	851 (90.5)	1,474 (90.5)
Non-Caucasian	66 (9.6)	89 (9.5)	155 (9.5)
Distant Stage Diagnosis	306 (44.4)	441 (46.9)	747 (45.9)
Non-Distant Stage Diagnosis	383 (55.6)	499 (53.1)	882 (54.1)
Avg. Age at Diagnosis (Yrs)	69.2	68.9	69.0

"Indian River" refers to the region of southeastern Sussex County made up by zip codes 19939, 19945, 19947, 19966, 19970, and 19975; "non-Indian River" refers to the remainder of Sussex County that falls outside of the six zip code region. Source: DCR, 2009.

B. Indian River Lung Cancer Incidence Rates

Indian River lung cancer incidence rates were significantly higher than rates for Sussex County, Delaware, and the U.S. for the 2000-04 and 2001-05 time periods (Table 4).

Table 4: Average Annual Age-Adjusted Lung Cancer Incidence Rates: 2000-04 and 2001-05

	2000-04	**2001-05**
United States	63.0 (62.5, 63.4)	62.7 (62.3, 63.1)
Delaware	76.9 (74.3, 79.5)	78.9 (76.3, 81.5)
Sussex	79.1 (74.1, 84.1)	83.4 (78.3, 88.5)
Indian River	**105.6** (95.6, 115.5)	**107.4** (97.3, 117.4)

All rates are per 100,000 population and age-adjusted to the 2000 U.S. standard population.
Values in parentheses represent lower and upper 95% confidence limits.
Bolded rates are significantly elevated compared to the Sussex County, Delaware, and U.S. rates.
"Indian River" refers to the region of southeastern Sussex County made up by zip codes 19939, 19945, 19947, 19966, 19970, and 19975. Sources: Surveillance, Epidemiology, and End Results Program, National Cancer Institute, 2009; DCR, 2009.

The rates in Table 4 should be interpreted as the average number of new lung cancer cases diagnosed per 100,000 residents each year from 2000-04 and 2001-05. For example, each year from 2001-05, an average of 107.4 cases of lung cancer were diagnosed for every 100,000 Indian River residents.

In reality, fewer than 100,000 residents live in the Indian River area; therefore, the actual number of new lung cancer cases diagnosed annually in the Indian River area is slightly lower than 107.4. From 2000-04, an average of 86 cancer cases were diagnosed annually in Indian River. From 2001-05, an average of 88 cancer cases were diagnosed annually in Indian River.

As shown in Table 4, the confidence intervals for the 2000-04 and 2001-05 Indian River lung cancer rates do not overlap with the confidence intervals for the Sussex County, Delaware, and U.S. rates. Therefore, both Indian River rates (2000-04 and 2001-05) are significantly elevated compared to the county, state, and national rates. To signify the fact that they are significantly greater than county, state, and national rates, both Indian River lung cancer rates appear in bold.

C. Indian River Lung Cancer Incidence Rates, by Sex

Elevated lung cancer rates in the Indian River area are confined to males only. As shown in Table 5, for 2000-04 and 2001-05, lung cancer rates for Indian River males were significantly higher than the male lung cancer rates for Sussex County, Delaware, and the U.S. However, lung cancer rates for Indian River females were not significantly elevated compared to the female lung cancer rates for the county or state for either 5-year time period.

The 2000-04 lung cancer rate for Indian River males (141.8 per 100,000) was 86% higher than the lung cancer rate for Indian River females (76.1 per 100,000). Similarly, the 2001-05 lung cancer rate for Indian River males (147.1 per 100,000) was 91% higher than the lung cancer rate for Indian River females (76.9 per 100,000).

In relation to the state as a whole, the 2001-05 lung cancer rate for Indian River males was 51% higher than the rate for Delaware males. For Indian River females, the 2001-05 lung cancer rate was only 17% higher than the rate for Delaware females. Thus, the overall Indian River lung cancer rate (for both sexes combined) is being driven up by the lung cancer rate for Indian River males.

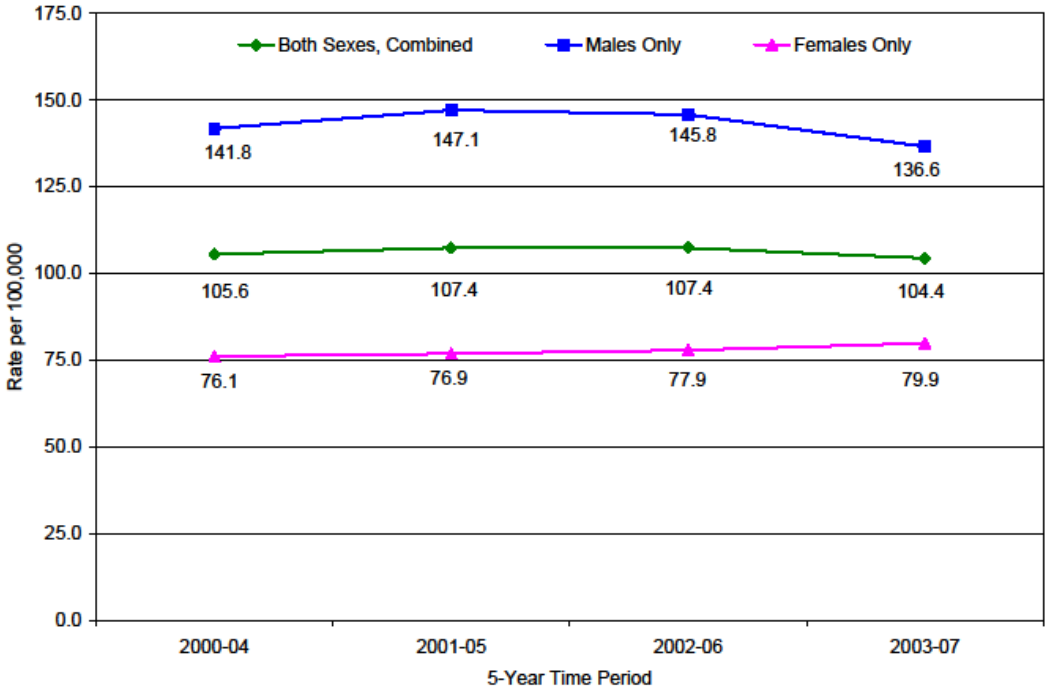
Table 5: Five-Year Average Annual Age-Adjusted Lung Cancer Incidence Rates, by Sex

	2000-04			2001-05		
	Total	**Male**	**Female**	**Total**	**Male**	**Female**
United States	63.0 (62.5, 63.4)	79.1 (78.4, 79.9)	51.3 (50.8, 51.8)	62.7 (62.3, 63.1)	77.7 (76.9, 78.4)	51.9 (51.4, 52.4)
Delaware	76.9 (74.3, 79.5)	97.2 (92.8, 101.6)	62.6 (59.4, 65.8)	78.9 (76.3, 81.5)	97.2 (92.8, 101.6)	65.7 (62.5, 68.9)
Sussex	79.1 (74.1, 84.1)	101.2 (92.8, 109.6)	61.6 (55.5, 67.7)	83.4 (78.3, 88.5)	104.5 (96.0, 113.0)	67.2 (61.0, 73.5)
Indian River	**105.6** (95.6, 115.5)	**141.8** (124.7, 158.8)	76.1 (64.4, 87.7)	**107.4** (97.3, 117.4)	**147.1** (129.6, 164.5)	76.9 (65.2, 88.5)

All rates are per 100,000 population and age-adjusted to the 2000 U.S. standard population.
Values in parentheses represent lower and upper 95% confidence limits.
Bolded rates are significantly elevated compared to the Sussex County, Delaware, and U.S. rates.
"Indian River" refers to the region of southeastern Sussex County made up by zip codes 19939, 19945, 19947, 19966, 19970, and 19975. Sources: Surveillance, Epidemiology, and End Results Program, National Cancer Institute, 2009; DCR, 2009.

Figure 4 illustrates the extent to which lung cancer rates for Indian River males exceed those of Indian River females.

Figure 4: Average Annual Age-Adjusted Lung Cancer Incidence Rates for the Indian River Area, Delaware, Rolling 5-Year Averages: 2000-07



All rates are per 100,000 population and age-adjusted to the 2000 U.S. standard population.
Source: DCR, 2009.

In summation, DCR surveillance data show that the overall Indian River lung cancer rate (for both sexes combined) is significantly elevated compared to the lung cancer rates for Sussex County, Delaware, and the U.S. However, when rates are examined for males and females separately, only Indian River males have an elevated lung cancer rate. Therefore, males account for virtually all of the elevation in lung cancer rates for the Indian River area. The lung cancer rate for Indian River females is not higher than would normally be expected given the female lung cancer rates for Sussex County and Delaware as a whole.

The next several sections review findings from the IRCLS.

D. IRCLS Participant Demographics

A total of 163 Sussex County residents took part in the IRCLS; 71 participants (43.6%) had been diagnosed with lung cancer and 86 participants (52.8%) were cancer-free. Six proxy surveys (3.9%) were completed by individuals who had an immediate family member recently pass away from lung cancer. DPH combined data from lung cancer participants and proxy reporters to yield a total lung cancer sample of N=77.

Thirty-four of the 77 lung cancer participants (44.2%) were Indian River residents at the time of diagnosis; the remaining 43 lung cancer participants (55.8%) were non-Indian River residents at the time of diagnosis. Of the 86 cancer-free participants, 29 (33.7%) were Indian River residents; the remaining 57 cancer-free participants (66.3%) were non-Indian River residents.

Participant demographics, broken down by lung cancer status and Indian River status, are displayed in Table 6.

Table 6: Demographic Composition of the Indian River Community-Level Survey Participants (N=163), by Lung Cancer Status, Delaware, 2009

	Indian River N (%)			Non-Indian River N (%)		
	LC	**CF**	**Total**	**LC**	**CF**	**Total**
Total	34	29	63	43	57	100
Sex						
Male	17 (50.0)	13 (44.8)	30 (47.6)	18 (41.9)	23 (40.3)	41 (41.0)
Female	17 (50.0)	16 (55.2)	33 (52.4)	25 (58.1)	34 (59.6)	59 (59.0)
			p=ns			*p=ns*
Race						
Caucasian	33 (97.1)	29 (100.0)	62 (98.4)	41 (95.3)	57 (100.0)	98 (98.0)
Non-Caucasian	0 (0.0)	0 (0.0)	0 (0.0)	2 (4.6)	0 (0.0)	2 (2.0)
Missing/Refused	1 (2.9)	0 (0.0)	1 (1.6)	0 (0.0)	0 (0.0)	0 (0.0)
			p=ns			*p=ns*
Average Age (Yrs)*	70.2	70.7	70.4	67.7	71.9	70.2
			p=ns			***p<0.05***
Marital Status						
Married/Partnered	25 (73.5)	23 (79.3)	48 (76.2)	30 (69.8)	44 (77.2)	74 (74.0)
Single	9 (26.5)	6 (20.7)	15 (23.8)	13 (30.2)	13 (22.8)	26 (26.0)
			p=ns			*p=ns*
Education						
Less than H.S.	10 (29.4)	2 (6.9)	12 (37.5)	10 (23.2)	6 (10.5)	16 (16.0)
H.S. or GED	13 (38.2)	10 (34.5)	23 (36.5)	14 (32.6)	3 (5.3)	17 (17.0)
Some College	9 (26.5)	12 (41.4)	21 (33.3)	13 (30.2)	12 (21.0)	25 (25.0)
4-yr Degree or more	2 (5.9)	5 (17.2)	7 (11.1)	6 (14.0)	36 (63.2)	42 (42.0)
			p=ns			***p<0.0001***
Income (annual)						
Less than $20,000	7 (20.6)	0 (0.0)	7 (11.1)	8 (18.6)	2 (3.5)	10 (10.0)
$20-39,999	18 (52.9)	13 (44.8)	31 (49.2)	14 (32.6)	9 (15.8)	23 (23.0)
$40-59,999	4 (11.8)	5 (17.2)	9 (14.3)	8 (18.6)	18 (31.6)	26 (26.0)
$60,000 or more	4 (11.8)	7 (24.1)	11 (17.5)	8 (18.6)	20 (35.1)	28 (28.0)
Missing/Refused	1 (2.9)	4 (13.8)	5 (7.9)	5 (11.6)	8 (14.0)	13 (13.0)
			p<0.05			***p<0.05***
Employment Status						
Currently Employed	12 (35.3)	2 (6.9)	14 (22.2)	10 (23.2)	7 (12.2)	17 (17.0)
Homemaker	2 (5.9)	1 (3.4)	3 (4.8)	2 (4.6)	1 (1.8)	3 (3.0)
Unable to work	2 (5.9)	0 (0.0)	2 (3.2)	4 (9.3)	0 (0.0)	4 (4.0)
Retired	17 (50.0)	26 (89.6)	43 (68.2)	27 (62.8)	49 (86.0)	76 (76.0)
			p<0.05			***p<0.05***

Lung cancer totals include data from participants diagnosed with lung cancer and proxy reporter data.
LC=lung cancer participants; CF=cancer-free participants; ns=not significant.

*****Average ages for lung cancer participants exclude proxy report data. Source: IRCLS data, 2009.

Chi-square and t-tests (α=0.05) were used to identify significant differences between lung cancer and cancer-free participants in the Indian River and non-Indian River areas. In Table 7, p-values listed as "*ns*" signify that lung cancer and cancer-free participants did not significantly differ with respect to a demographic variable.

Among Indian River participants, lung cancer and cancer-free participants were similar with respect to sex, race, age, marital status, and education. However, lung cancer participants had less income and were more likely to be employed compared to cancer-free participants.

In the non-Indian River area, lung cancer and cancer-free participants were similar with respect to sex, race, and marital status. However, lung cancer patients were younger, had less education and income, and were more likely to be employed compared to cancer-free participants.

Of these demographic variables, age is most highly correlated with lung cancer risk. Therefore, this demographic profile may slightly underestimate odds ratio estimates for non-Indian River participants.

E. Risk Factor Prevalence Rates

Using self-report data from participants, DPH calculated risk factor prevalence rates for 12 lung cancer risk factors (Table 7). For the purposes of IRCLS analyses, risk factor variables were operationally defined as follows:

1. "Ever smokers" included participants who had smoked more than 100 cigarettes in their lifetime or, in the absence of cigarette smoking, had smoked more than 20 cigars and/or 20 pipes in their lifetime.

2. "Current smokers" included participants who (a) ever used cigarettes, cigars, or pipes regularly and (b) were currently using cigarettes, cigars, or pipes at the time of data collection. For the purposes of calculating odds ratios, current smokers were compared to participants who met the criteria for ever smoking but who were not currently smoking at the time of data collection.

3. Heavy smoking was defined as smoking more than one pack of cigarettes per day for more than 25 years. For the purposes of calculating odds ratios, heavy smokers were compared to participants who met the criteria for ever smoking but did not reach the threshold for heavy smoking.

4. IRCLS participants provided self-report data on the total length of time during which they smoked tobacco (cigarettes, cigars, and/or pipes). To create the long-term tobacco use risk factor variable, ever smokers were divided into two categories: those who had smoked tobacco for 25 years or more and those who had smoked tobacco for less than 25 years.

5. Secondhand smoke exposure remains a major public health problem, with more than 3,000 non-smokers in the U.S. dying from lung cancer each year.[10] Workers exposed to secondhand smoke on the job have a 24% increased risk of developing lung cancer.[11] Non-smoker wives living with smoker husbands have a 20% higher risk of dying from lung cancer compared to non-smoker wives living with non-smoker husbands.[12]

The IRCLS survey asked participants about secondhand smoke exposure at home and at work. A large proportion of participants (67.5%) reported dual exposure to secondhand smoke in both the home and work settings. IRCLS analyses considered participants to have experienced secondhand smoke exposure if they answered affirmatively to at least one of the following two questions: "Did you ever live with someone who regularly smoked cigarettes, cigars, or pipes indoors, including the home or car?" and "Did you ever work at a job where employees were allowed to smoke indoors?"

6. In the past, family history of lung cancer (known familial aggregation) has been explained away by the fact that family members share similar lifestyle behaviors or exposure histories.[13] However, recent research suggests that some individuals may have a genetic predisposition to lung cancer. Smokers who have had a first-degree relative diagnosed with early-onset lung cancer have a higher risk of developing lung cancer, themselves, compared to smokers without a family history.[14]

IRCLS participants provided data on whether any first-degree relatives (defined as parents, grandparents, siblings, or children) had previously been diagnosed with lung cancer. Participants who answered affirmatively were considered to have a family history of lung cancer.

7. Research shows that a history of nonmalignant lung disease (including chronic bronchitis and emphysema) is significantly associated with lung cancer risk.[15] Even among nonsmokers, there is an association between chronic bronchitis and lung cancer. IRCLS participants were asked if they had ever been told by a health professional that they had chronic bronchitis or emphysema. Participants who answered affirmatively were considered to have a history of nonmalignant lung disease.

8. Research confirms that workers in certain industries are at an increased risk of developing lung cancer.[16-18] As part of the IRCLS, participants were asked if they had ever worked in one or more of the following five high-risk industries: (a) agricultural, (b) chemical, (c) construction, (d) manufacturing, or (e) pharmaceutical. Participants who reported working in at least one of these fields met the threshold for previous work experience in a high-risk industry.

9. In addition to asking participants if they had worked in a high-risk industry, IRCLS survey items assed whether participants were ever exposed to one or more of 20 different known lung carcinogens while at work. (See Appendix A for a complete list of carcinogens included in the IRCLS survey). Participants who answered affirmatively were considered to have experienced workplace exposure to carcinogens.

10. Research has identified an association between drinking water contaminants and cancer risk. Chlorination by-products in drinking water are associated with increased risk of overall cancer.[19] Arsenic levels in well water are associated with increased risk of lung cancer.[20] The U.S. Environmental Protection Agency (EPA) mandates that public water supplies are routinely tested for microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides. However, if a resident receives their drinking water through a private well, routine safety testing it the responsibility of the resident.

Because private well water is not regulated to the same extent as public water supplies, the IRCLS survey included private well water as a potential lung cancer risk factor. Participants who reported ever living in a residence that received water from a private well were compared to participants who reported never living in such a residence.

11. The U.S. EPA states that smoke from improperly burned wood (e.g., wood burned at a low smolder) contains several lung carcinogens. Without proper ventilation, these substances may be inhaled over time, causing serious damage to lung tissue.[21] Indoor wood burning was included in the IRCLS as a potential lung cancer risk factor. Participants were asked if they had ever used wood burning as the primary way to heat their home.

12. In the past, citizens have expressed concern about possible environmental exposure to carcinogens stemming from heavy industrial/agricultural zones in Sussex County. Because of

this, IRCLS analyses included long-term Sussex County residency (15 years or more) as a potential lung cancer risk factor. IRCLS participants who reported living in Sussex County for 15 years or more (regardless of the total number of locations they lived within the county) were compared to participants who had moved to Sussex County less than 15 years before the IRCLS.

Table 7: Risk Factor Prevalence Rates, Indian River vs. Non-Indian River, Indian River Community-Level Survey, Delaware, 2009

	Indian River		Non-Indian River	
	LC (%)	CF (%)	LC (%)	CF (%)
1. Ever smoker				
Yes	97.1	75.9	93.0	68.4
No	2.9	24.1	7.0	31.6
2. Current smoker				
Yes	45.5	4.5	41.0	5.1
No	54.5	95.5	59.0	94.9
3. Heavy Smoker				
Yes	66.7	50.0	52.5	23.1
No	33.3	50.0	47.5	76.9
4. Smoked ≥ 25 Years				
Yes	81.2	59.0	70.3	39.4
No	18.8	40.9	29.7	60.6
5. Secondhand Smoke Exposure				
Yes	94.1	100.0	97.7	89.5
No	5.9	0.0	2.3	10.5
6. Family History of Lung Cancer				
Yes	26.5	10.7	18.6	7.1
No	73.5	89.3	81.4	92.9
7. Chronic Bronchitis / Emphysema				
Yes	64.7	79.3	30.2	8.8
No	35.3	20.7	69.8	91.2
8. Worked in High-Risk Industry				
Yes	73.5	44.8	55.8	29.8
No	26.5	55.2	44.2	70.2
9. Workplace Exposure to Carcinogens				
Yes	61.8	65.5	79.1	40.4
No	38.2	34.5	20.9	59.6
10. Private Well Water at Residence				
Yes	79.4	72.4	71.4	59.6
No	20.6	27.6	28.6	40.4
11. Wood Burning to Heat Residence				
Yes	17.6	31.0	30.2	19.3
No	82.3	69.0	69.8	80.7
12. Sussex County Resident ≥15 Years				
Yes	50.0	27.6	69.8	29.8
No	50.0	72.4	30.2	70.2

LC = participants with lung cancer; CF = cancer-free participants.
Source: IRCLS data, 2009.

Within the Indian River area, compared to cancer-free participants, a larger percentage of lung cancer participants were ever smokers, current smokers, and heavy smokers. Lung cancer participants were also more likely than cancer-free participants to have smoked tobacco for 25

or more years, to have a family history of lung cancer, to have worked in a high-risk industry, to have lived in a residence that received private well water, and to have lived in Sussex County for 15 or more years.

Within the non-Indian River area, lung cancer participants were more likely than cancer-free participants to have each of the 12 risk factors listed in Table 7.

F. Risk Factor Odds Ratios

To identify whether any of the 12 risk factor variables were significantly associated with a diagnosis of lung cancer, DPH calculated risk factor odds ratios (Table 8). Statistically significant odds ratios appear in bold font. If an odds ratio was statistically significant (i.e., bolded), individuals with the risk factor were significantly more likely than those without the risk factor to have developed lung cancer. If an odds ratio was not statistically significant (i.e., not bolded), individuals with the risk factor were no more likely than those without the risk factor to have developed lung cancer.

Table 8: Risk Factor Odds Ratios, Indian River vs. Non-Indian River, Indian River Community-Level Survey, Delaware, 2009

	Indian River			Non-Indian River		
	LC (N)	**CF (N)**	**Odds Ratio**	**LC (N)**	**CF (N)**	**Odds Ratio**
1. Ever smoker						
Yes	33	22	**10.5** (1.2, 91.4)	40	39	**6.2** (1.7, 22.6)
No	1	7	p<0.05	3	18	p<0.01
2. Current smoker						
Yes	15	1	**17.5** (2.1, 145.8)	16	2	**12.9** (2.7, 61.2)
No	18	21	p<0.01	23	37	p<0.001
3. Heavy Smoker						
Yes	22	11	2.0 (0.7, 6.0)	21	9	**3.7** (1.4, 9.7)
No	11	11	p=0.22	19	30	p<0.01
4. Smoked ≥ 25 Years						
Yes	26	13	3.0 (0.9, 10.3)	26	13	**3.6** (1.4, 9.8)
No	6	9	p=0.07	11	20	p<0.01
5. Secondhand Smoke Exposure						
Yes	32	29	0.2 (0.0, 2.5)	42	51	4.9 (0.6, 42.7)
No	2	0	p=0.18	1	6	P=0.1116
6. Family History of Lung Cancer						
Yes	9	3	3.0 (0.7, 12.4)	8	4	3.0 (0.8, 10.6)
No	25	25	p=0.12	35	52	p=0.08
7. Chronic Bronchitis / Emphysema						
Yes	22	23	2.1 (0.7, 6.5)	13	5	**4.5** (1.5, 13.9)
No	12	6	p=0.20	30	52	p<0.01
8. Worked in High-Risk Industry						
Yes	25	13	**3.4** (1.2, 9.8)	24	17	**3.0** (1.3, 6.8)
No	9	16	p<0.05	19	40	p<0.01
9. Workplace Exposure to Carcinogens						
Yes	21	19	0.9 (0.3, 2.4)	34	23	**5.6** (2.3, 13.8)
No	13	10	p=0.75	9	34	p<0.001
10. Private Well Water at Residence						
Yes	27	21	1.5 (0.5, 4.7)	30	34	1.7 (0.7, 4.0)
No	7	8	p=0.52	12	23	p=0.22
11. Wood Burning to Heat Residence						
Yes	6	9	0.5 (0.2, 1.6)	13	11	1.8 (0.7, 4.6)
No	28	20	p=0.21	30	46	p=0.20)
12. Sussex County Resident ≥15 Years						
Yes	17	8	2.6 (0.9, 7.6)	30	17	**5.4** (2.3, 12.9)
No	17	21	p=0.07	13	40	p<0.001

Bolded odds ratios are statistically significant.
Values in parentheses represent lower and upper 95% confidence limits.
LC = participants with lung cancer; CF = cancer-free participants.
Source: IRCLS data, 2009.

Odds ratios (OR) displayed in Table 8 are explained below:

1. In both the Indian River and non-Indian River areas, ever smokers were significantly more likely to have developed lung cancer compared to never smokers. Within Indian River, ever smokers had 10.5 times higher odds of having developed lung cancer compared to those who never smoked. Outside of Indian River, ever smokers had 6.2 times higher odds of having developed lung cancer compared to never smokers.

2. In both the Indian River and non-Indian River areas, current smokers were significantly more likely than non-current smokers to have developed lung cancer. Within Indian River, the odds of developing lung cancer were 17.5 times higher among current smokers than non-current smokers. Outside of Indian River, current smokers had 12.9 times higher odds of developing lung cancer compared to non-current smokers.

3. The non-significant odds ratio of 2.0 indicates that within Indian River, heavy smokers were no more likely to have developed lung cancer than non-heavy smokers. However, in the non-Indian River area, heavy smokers were significantly more likely than non-heavy smokers to have developed lung cancer (OR=3.7).

4. Similarly, the non-significant odds ratio of 3.0 indicates that within Indian River, a diagnosis of lung cancer was no more likely among participants who had smoked tobacco for 25 years or more compared to participants who had smoked tobacco for less than 25 years. On the other hand, among participants in the non-Indian River area, individuals who had smoked tobacco 25 or more years were significantly more likely to have developed lung cancer compared to those who had smoked tobacco for 25 years or less (OR=3.6).

5. Regardless of whether they lived within the Indian River or non-Indian River areas, the odds of having developed lung cancer were not significantly higher among participants who had been exposed to secondhand smoke either at work or at home (OR=0.2 for the Indian River area and OR=4.9 for the non-Indian River area).

6. Within the sample of IRCLS participants, regardless of whether they lived inside or outside of the Indian River area, the odds of having developed lung cancer were not significantly higher among participants who had an immediate family member (parent, grandparent, sibling, or child) diagnosed with lung cancer (OR=3.0 for both the Indian River and non-Indian River areas).

7. Within Indian River, the non-significant odds ratio of 2.1 indicates that participants with chronic bronchitis or emphysema were no more likely to have developed lung cancer compared to participants without these conditions. On the other hand, in the non-Indian River area, participants with chronic bronchitis or emphysema were significantly more likely than those without the conditions to have developed lung cancer (OR=4.5).

8. Within Indian River, the significant odds ratio indicates that participants who had worked in one or more of these high-risk industries had 3.4 times greater odds of having developed lung cancer compared to those who had never worked in these high-risk industries. In the non-Indian River area, participants who reported having worked in one or more of these industries were also significantly more likely to have developed lung cancer (OR=3.0).

9. Inside Indian River, the non-significant odds ratio of 0.9 indicates that participants who experienced on-the-job exposure to lung carcinogens were no more likely to have developed lung cancer compared to those who reported no job-related exposure. However, in the non-Indian River area, participants who reported job-related exposure to one or more lung carcinogens were significantly more likely to have developed lung cancer compared to those who experienced no job-related exposure (OR=5.6).

10. Among IRCLS participants, regardless of whether they lived inside or outside of the Indian River area, participants who had ever lived in a residence that received private well water were no more likely to have developed lung cancer compared to participants who never lived in such a residence (OR=1.5 for the Indian River area and OR=1.7 for the non-Indian River area).

11. Among IRCLS participants, regardless of whether they lived inside or outside of the Indian River area, participants who had ever used wood burning as the primary way to heat the home were no more likely to have developed lung cancer compared to participants who had never used wood burning as the primary home heating method (OR=0.5 for the Indian River area and OR=1.8 for the non-Indian River area).

12. Within Indian River, the non-significant odds ratio of 2.6 indicates that residents who had lived in Sussex County for 15 years or more were no more likely to have developed lung cancer compared to participants who had resided in Sussex County for less than 15 years. However, in the non-Indian River area, the odds ratio for long-term Sussex County residency reached a level of statistical significance. That is, in the non-Indian River area, participants who had resided in Sussex County for 15 years or more were 5.4 times more likely to have developed lung cancer compared to those who had lived in Sussex County for less than 15 years.

G. Risk Factor Prevalence: Indian River vs. Non-Indian River

Next, DPH investigated differences in risk factor prevalence rates between Indian River and non-Indian River residents (Table 9). As opposed to the risk factor prevalence rates in Table 7, risk factor prevalence rates in Table 9 were calculated by pooling data for lung cancer participants and cancer-free participants in each of the two areas. Because they were not calculated separately for lung cancer and cancer-free participants, prevalence rates apply to all participants regardless of lung cancer status.

If risk factor prevalence rates for Area A and Area B were similar, residents in the two areas behaved similarly with respect to that risk factor. If the risk factor prevalence rate for Area A was much greater than that for Area B, residents in Area A were more likely to engage in that risk factor.

Chi-square tests (α=0.05) were used to identify statistically significant differences in risk factor prevalence rates between the Indian River and non-Indian River areas. P-values listed as "*ns*" signify that the difference in risk factor prevalence between the Indian River and non-Indian River areas did not reach a level of statistical significance.

Table 9: Risk Factor Prevalence Rates, by Indian River Status, Indian River Community-Level Survey, Delaware, 2009

	Indian River	Non-Indian River	χ^2 p-value
1. Ever smoker	87.1%	79.0%	*ns*
2. Current smoker	29.1%	23.1%	*ns*
3. Heavy Smoker	60.0%	38.0%	p<0.05
4. Smoked ≥ 25 Years	72.2%	55.7%	*ns*
5. Secondhand Smoke Exposure	96.8%	93.0%	*ns*
6. Family History of Lung Cancer	19.4%	12.1%	*ns*
7. Chronic Bronchitis / Emphysema	28.6%	18.0%	*ns*
8. Worked in High-Risk Industry	60.3%	41.0%	p<0.05
9. Workplace Exposure to Carcinogens	63.5%	57.0%	*ns*
10. Private Well Water at Residence	76.2%	64.6%	*ns*
11. Wood Burning to Heat Residence	23.8%	24.0%	*ns*
12. Sussex County Resident ≥15 Years	40.3%	47.0%	*ns*

"*ns*"=not significant. Source: IRCLS data, 2009.

With the exception of using wood burning to heat the residence and residing in Sussex County for 15 years or more, the prevalence rate for all lung cancer risk factors were higher for the Indian River area than for the non-Indian River area. For two of the 12 risk factors – "heavy smoker" and "worked in a high-risk industry" – the difference in prevalence rates between the two areas reached a level of statistical significance. In other words, regardless of lung cancer status, Indian River participants were significantly more likely than non-Indian River participants to be heavy smokers and to have worked in the agricultural, chemical, construction, manufacturing, or pharmaceutical industries.

The data in Table 9 suggest that compared to non-Indian River residents, Indian River residents were more likely as a whole to engage in known lung cancer risk factors. Stated differently, compared to their neighbors, Indian River residents may have a unique lung cancer risk profile. Tobacco use and occupational exposure may not be limited to the population of Indian River residents already diagnosed with lung cancer. Rather, cancer-free Indian River residents may also have these risk factors, placing them at increased risk for eventual development of lung cancer.

Discussion

A. DCR Surveillance Data Summary

The 2000-04 and 2001-05 lung cancer incidence rates for Indian River were significantly elevated compared to lung cancer rates for Sussex County, Delaware, and the U.S.

However, when rates were calculated separately for males and females, it becomes obvious that males account for virtually all of the elevation in the Indian River lung cancer incidence rate. For 2000-04 and 2001-05, lung cancer rates for Indian River males were significantly elevated compared to rates for Sussex County, Delaware, and the U.S. However, lung cancer rates for Indian River females were not significantly elevated compared to the county and state rates for either 5-year time period.

This is an important finding as previous research shows that females are more susceptible than males to non-tobacco lung cancer risk factors. Compared to non-smoking men, men who smoke cigarettes are 23 times more likely to develop lung cancer. However, the increase in risk is much less pronounced among women. Compared to non-smoking women, women who smoke cigarettes are just 13 times more likely to develop lung cancer.[4] Another recent study analyzed data from six large-scale cohort studies and found consistently higher lung cancer incidence rates among non-smoking women compared to non-smoking men.[22]

The fact that elevated lung cancer rates in the Indian River area are confined to males supports the assertion that the elevated lung cancer rate in the Indian River area is not primarily attributable to environmental exposure. If Indian River residents were being exposed to environmental hazards capable of causing lung cancer, one would expect lung cancer incidence rates to be particularly elevated among females. Rather, data from the IRCLS suggest that lifestyle behaviors and/or occupational exposure are contributing to elevated lung cancer rates in the Indian River area.

B. IRCLS Data Summary

The IRCLS was a survey-based study designed to identify factors contributing to the elevated lung cancer incidence rate in the Indian River area. Participants provided data on multiple lung cancer risk factors, including tobacco use, occupational exposure, environmental exposure, personal health history, family history of lung cancer, and other lifestyle behaviors.

Risk factor prevalence rates in Table 7 demonstrate that for the majority of lung cancer risk factors investigated, lung cancer participants were more likely than cancer-free participants to have the risk factor.

Odds ratios were calculated to determine if participants with one or more of 12 lung cancer risk factors were more likely to have developed the disease compared to participants without risk factors. Odds ratios were calculated for two populations: (a) Indian River participants (lung cancer vs. cancer-free) and (b) non-Indian River participants (lung cancer vs. cancer-free).

Within Indian River, three lung cancer risk factors reached a level of statistical significance: (1) ever smokers were 10.5 times more likely to have developed lung cancer compared to never smokers; (2) current smokers were 17.5 times more likely to have developed the disease compared to non-current smokers; and (3) participants who had ever worked in one or more

high-risk industries were 3.4 times more likely to have developed lung cancer compared to those who had never worked in a high-risk industry.

Among non-Indian River participants, the four risk factor odds ratios that did *not* achieve a level of statistical significance were exposure to secondhand smoke, family history of lung cancer, ever having lived in a residence that received private well water, and ever having used wood burning as the primary method for heating the home. For the remaining eight risk factors, participants who had the risk factor were significantly more likely to have been diagnosed with lung cancer compared to those without the risk factor.

The fact that only 3 of the 12 risk factor odds ratios were statistically significant for the Indian River area may be due to several factors. For example, Indian River residents, both with and without lung cancer, may live similar lives and partake in similar risk factor behaviors. To this end, Indian River residents would not show substantial differences in risk factor prevalence regardless of whether they had been diagnosed with lung cancer. Alternatively, sample sizes for the IRCLS may have been too small to detect significant differences on risk factor prevalence between lung cancer and cancer-free participants in the Indian River area.

Regardless of lung cancer status, Indian River participants were significantly more likely than non-Indian River participants to be heavy smokers and to have worked in a high-risk industry. Thus, findings from the IRCLS suggest that the Indian River community may have a unique lung cancer risk factor profile compared to their non-Indian River neighbors. Tobacco use and occupational exposure may not be limited to the population of Indian River residents already diagnosed with the disease. Rather, a sizeable proportion of cancer-free Indian River residents may also have these risk factors, placing them at increased risk for eventual development of lung cancer.

Risk factor prevalence rates in Table 9 were calculated using lung cancer populations of variable size (34 lung cancer cases in the Indian River area vs. 43 lung cancer cases in the non-Indian River area). Given the difference in lung cancer populations between the two areas, one might argue that this is not a fair comparison. However, any bias would tend to increase risk factor prevalence rates among non-Indian River residents. Therefore, the risk factor prevalence rates in the Indian River community are likely under-estimated.

When considered as a whole, the findings presented in this report do not rule out tobacco use and occupational exposure as contributing factors to the elevated lung cancer rate in Indian River. This conclusion is based on the following findings:

- In the Indian River area, ever smokers and current smokers were significantly more likely to develop lung cancer compared to never smokers and non-current smokers, respectively.

- Odds ratios for ever smokers and current smokers were higher in the Indian River area than in the non-Indian River area.

- In the Indian River area, participants who reported ever having worked in one or more high-risk industries were significantly more likely to have developed lung cancer compared to those who had never worked in a high-risk industry.

- In the Indian River area, the lung cancer incidence rate is elevated for males only. The female lung cancer rate for the Indian River area is not significantly greater than the female lung cancer rate for Sussex County or Delaware.

- Regardless of lung cancer status, Indian River participants were significantly more likely than non-Indian River residents to be heavy smokers and to have ever worked in a high-risk industry.

In summary, the odds ratios in Table 8 identified tobacco use and occupational exposure as factors contributing to the elevated lung cancer rate in Indian River. However, the magnitude of these odds ratios (10.5 for ever smoking, 17.5 for current smoking, and 3.4 for working in a high-risk industry) indicate that tobacco use is the major factor that explains the original finding of elevated lung cancer in the Indian River area of Sussex County, Delaware.

C. Strengths of the IRCLS

The IRCLS was the first study in Delaware to systematically collect risk factor data for all Sussex County residents diagnosed with lung cancer. Typically, cancer investigations in Delaware are limited to the data reported to the DCR. Although the DCR contains a large amount of cancer data (including tumor information and treatment patterns), risk factor data are not regularly collected and reported to the DCR. In 2007, after the elevated lung cancer rate was detected in the Indian River area, attention shifted to uncovering the factors contributing to the elevated rate. Collecting risk factor data was the first step toward the goal of identifying the cause of the higher-than-expected lung cancer incidence rates in the Indian River area.

Other strengths of the IRCLS involved both the preparation of interviewers and data collection techniques. Interviewers completed several training sessions and mock interviews before data collection began. Also, participant data were collected using a standardized format survey. It is likely that these efforts improved the validity of participant data.

D. Limitations of the IRCLS

The IRCLS was designed specifically to investigate the association between lung cancer rates and selected risk factors such as tobacco use, occupational exposure, and Sussex County residency. This study was not intended to identify environmental risk factors for lung cancer or other disease endpoints in Indian River using biological samples or meteorological data.

As part of the IRCLS, DPH attempted to contact every Sussex County resident diagnosed with lung cancer as of January 1, 2004. However, a sizeable number of individuals from this population had already passed away at the time of participant recruitment. It is unknown whether risk factor data collected from the 77 lung cancer participants who took part in the IRCLS were reflective of the experiences of the total population of Sussex County residents diagnosed with lung cancer. It is possible that individuals who had passed away from lung cancer prior to the IRCLS had noticeably different lifestyle behaviors and exposure histories compared to the 77 lung cancer participants who took part in the study. Similarly, there is a possibility that the control groups were not representative of the total population of cancer-free Sussex County residents. If either of these scenarios were true, risk factor odds ratios and prevalence estimates presented in this report may be over- or under-estimated.

Findings from the IRCLS were derived from relatively small sample sizes. Compared to Indian River participants, more non-Indian River residents took part in the IRCLS (63 vs. 100 participants, respectively). Therefore, it is possible that small sample sizes obscured true risk

factor odds ratios and prevalence rates in the Indian River and non-Indian River areas. If this were the case, given the comparatively small sample size for Indian River participants, the results would tend to under-estimate the impact of risk factors on the odds of developing lung cancer in the Indian River area.

Finally, because the IRCLS collected retrospective data from participants, the impact of recall errors on study findings must be considered. Participants were asked to remember details of exposures or behaviors that may have occurred more than 50 years in the past. It is likely that some participants failed to remember specific details about past exposures and behaviors. Other participants may have even forgotten entire exposure episodes. While these recall errors reduce the accuracy of risk factor odds ratios and prevalence estimates, they do so by underestimating the impact of risk factors on the odds of developing lung cancer.

E. Moving Forward

Findings from the IRCLS suggest that tobacco use is the major contributing lung cancer risk factor in the Indian River area. Job-related exposure in high-risk industries also contributed to increased lung cancer risk in Indian River. Some of these exposures occurred in the past and, therefore, are not subject to intervention except for increased awareness about lung cancer risk. However, findings from the IRCLS also documented ongoing tobacco- and job-related exposure risks, suggesting the need for educational and smoking cessation interventions.

Additionally, surveillance data strongly support that prevention efforts should target Indian River males, specifically. While the Indian River lung cancer rate for males is substantially higher-than-expected, the lung cancer rate for females is not significantly different from the female lung cancer rates for Sussex County or Delaware.

Findings from this investigation strongly point to tobacco use and occupational exposure as the primary and secondary reasons, respectively, for the elevated lung cancer rates in Indian River. However, in the future, researchers may choose to investigate whether geographic proximity to the IRPP influences residents' lung cancer risk beyond that of tobacco use and occupational exposure. These studies would likely include meteorological, environmental, and/or biomonitoring data, as well as complete residential histories to account for lifetime environmental exposure.

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Appendix A: Lung Carcinogens Included in the IRCLS

1. Solvents
2. Asbestos
3. Mineral or mining dust
4. Silica
5. Gasoline, diesel fuel, or engine exhaust fumes
6. Welding fumes
7. Electroplating fumes
8. Ether
9. Pesticides
10. Arsenic
11. Nickel
12. Cadmium
13. Radon
14. Plutonium
15. Uranium
16. Vinyl chloride
17. Nickel chromates
18. Coal
19. Mustard gas
20. Formaldehyde

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